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Full 3D characterization of high aspect ratio microstructures

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The European Synchrotron
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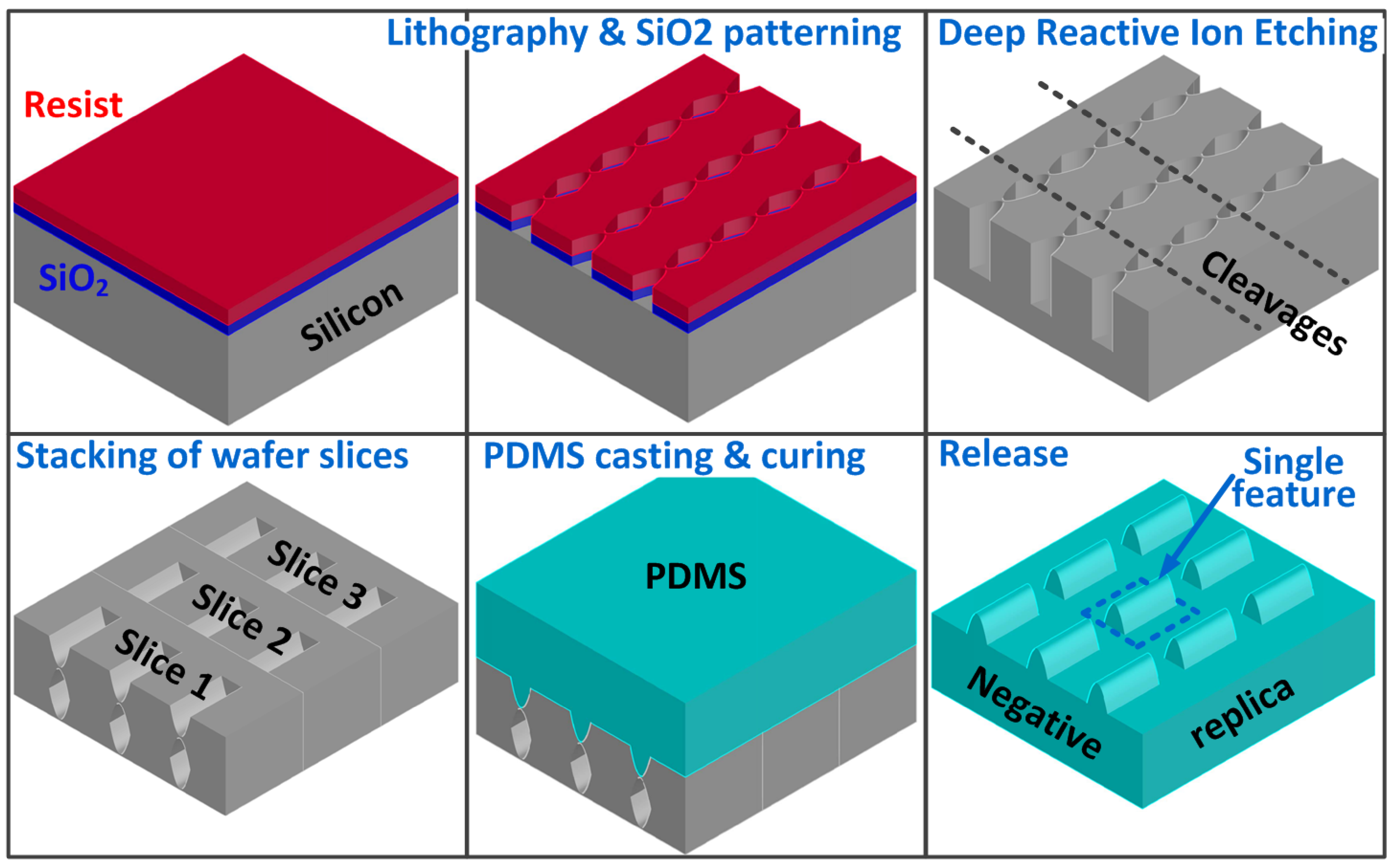
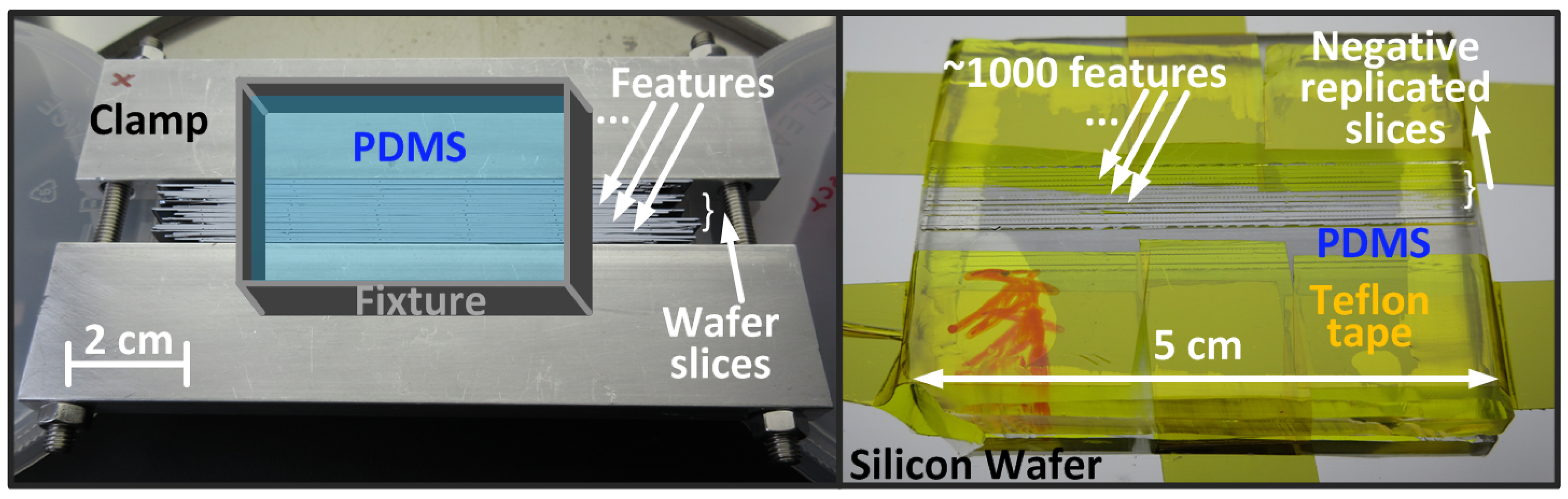
Motivation

The detailed full three-dimensional topography of high aspect ratio structures is crucial for the proper operation of a MEMS device. The engineering tolerances of geometries may approach the nanometer range. To fulfil the requirements in process development, process optimization and quality control, characterization techniques need to be adapted. High-aspect ratio micro structures often possess parts, such as cavities, undercuts, bottoms of trenches or holes, and sloped or vertical sidewalls, that complicate direct measurements with common characterization techniques. Regardless of their potential merits, optical profilers are limited by the maximum detectable slope and have relatively poor lateral resolution. Nowadays, AFMs have large scan fields and height-ranges exceeding 10 µm, which make them besides nano-scale measurements also interesting for more traditional profiling tasks. The finite widths of commercially available AFM cantilevers and the limited lengths of their tips compromise scanning of deep and shallow cavities. We circumvent this difficulty by polymer casting, thereby turning intrusions into negative replicas. This allows us to accurately characterize the complex geometries of the sidewalls of deep reactive ion etched cavities.

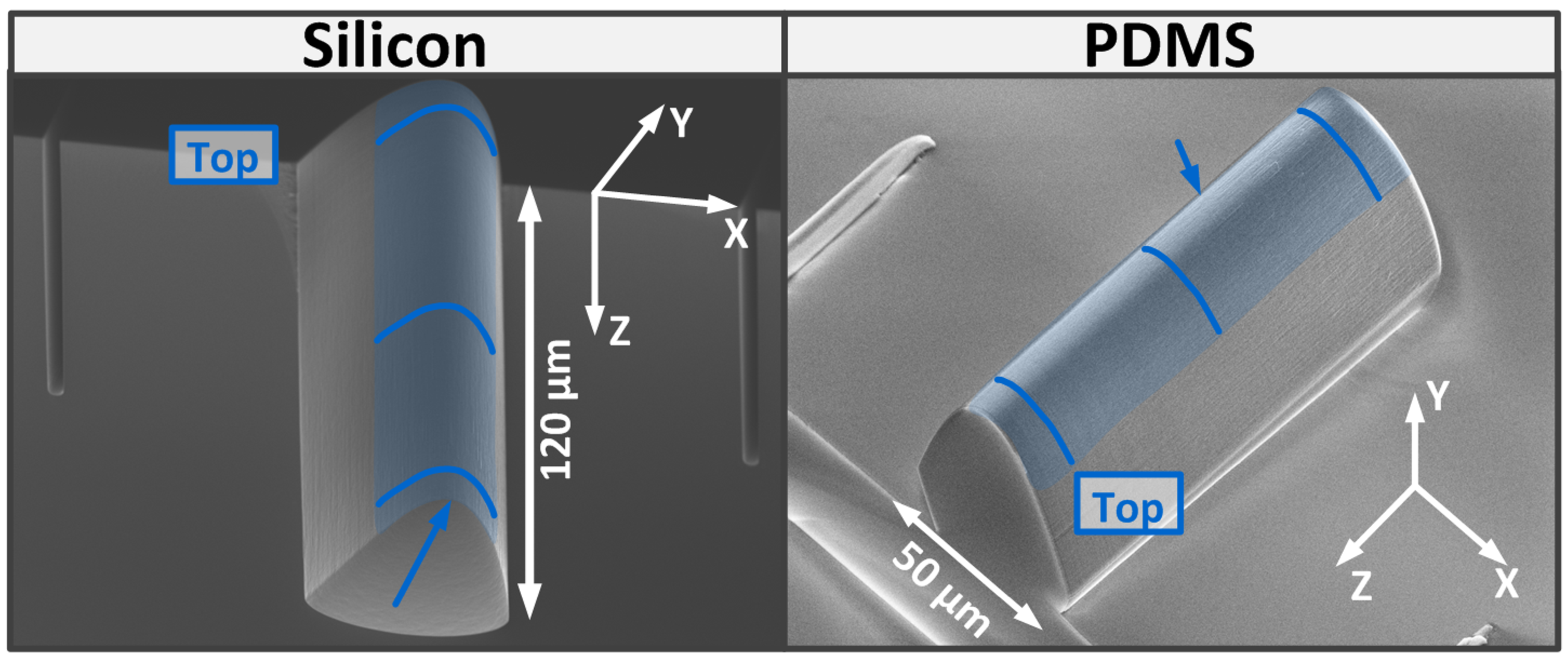
Microfabrication



The investigated micro structures are manufactured at DTU Danchip, the cleanroom facility of the Technical University of Denmark. The main processing steps are UV contact lithography and deep reactive ion etching for pattern transfer. To obtain a mold for polymer casting, wafers are manually cleaved into slices and these slices are stacked together and fixed with a purpose-made clamp. We choose PDMS (Sylgard 184) as a cast material due to its unique properties. It allows to replicate details in the nanometer range and its low elastic modulus facilitates the release from the mold without deforming the replicated features. Potentially, multiple cross sections from different wafers, which e.g. may have been processed with different etching recipes, can be integrated into a single PDMS sample. This facilitates especially extensive process optimization tasks, since alignment in the microscope only needs to be performed once.



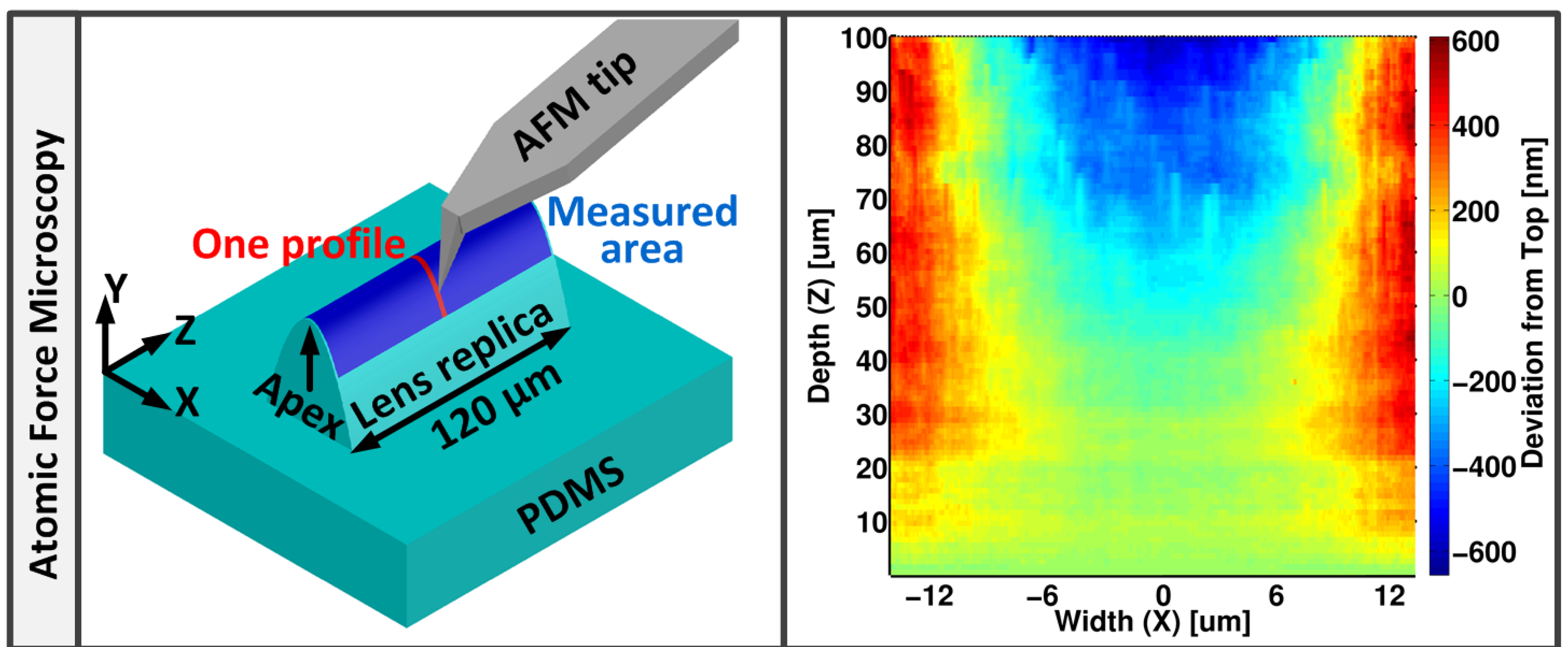
Features of interest

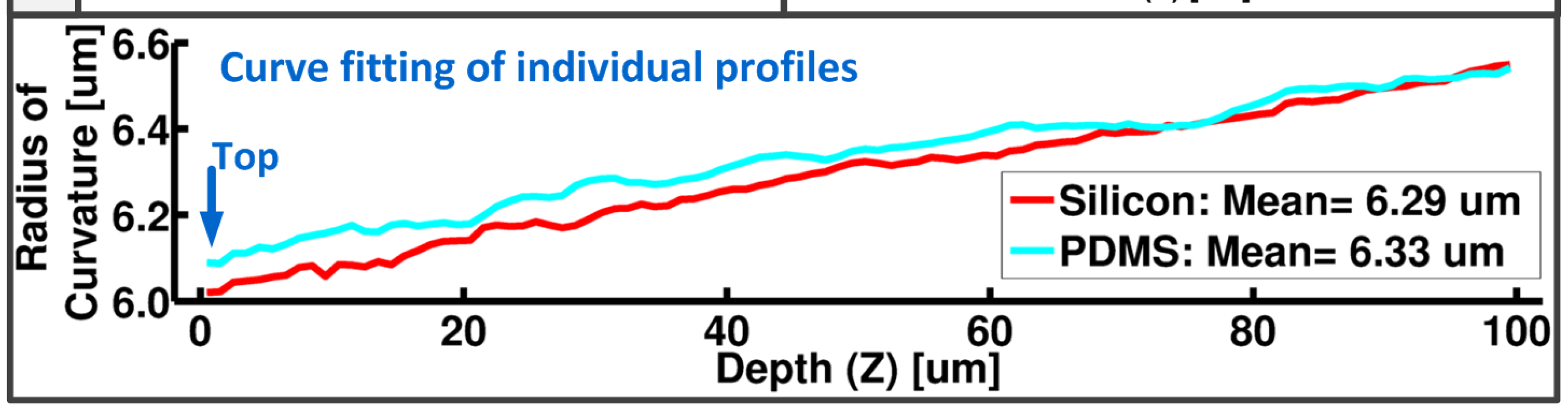


↑ Scanning electron micrographs of a cross section of a deep reactive ion etched cavity and a negative replica thereof in PDMS. The features have shapes of parabolic cylinders. The regions of interest are highlighted in blue.

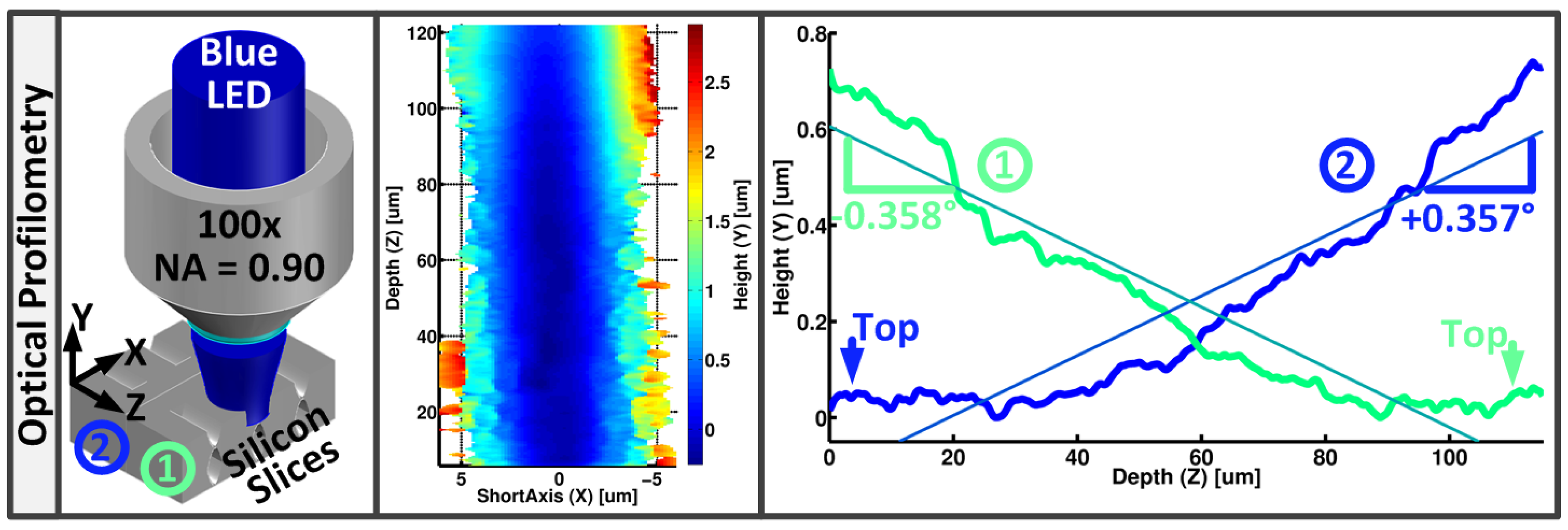
Characterization strategy

We use atomic force microscopy to scan the negative replicas of our silicon cross sections. We are mainly interested in the uniformity of our features. Especially the radius of curvature of the apex and its deviation along the depth (Z) are important. Scanning the silicon masters shows the high quality of the replication.

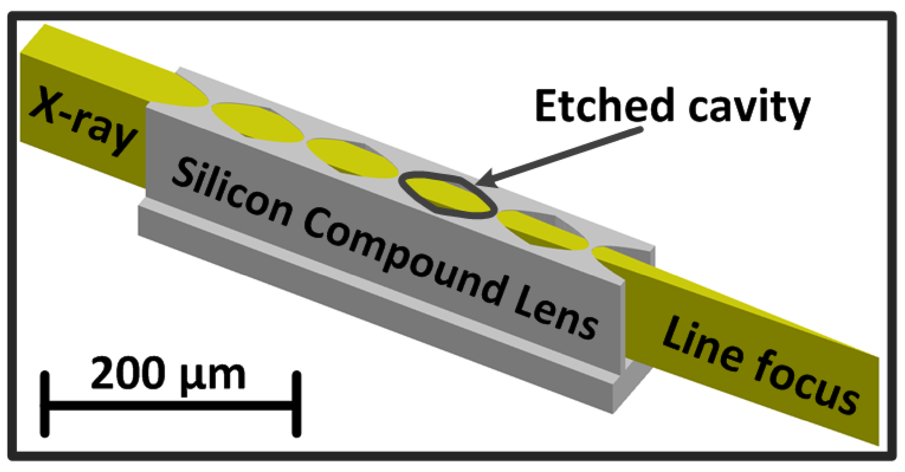




Confocal profilometry only yields a fraction of the information gained by atomic force microscopy. Nevertheless, its speed allows quick assesment of the sidewall slopes of the cross sections. Putting two samples back-to-back is used to level the data.



Application



Arrays of cavities with shapes of parabolic cylinders are used as lenses for shaping hard x-ray beams (E > 10 keV) at synchrotron facilities. In this way, focusing of x-ray beams down to waists of 50 nm with gains in flux density above 10^4 was already achieved [1,2]. Assisted by the proposed characterization technique, the manufacture of silicon lenses will be optimzed. The authors aim to generate hard x-ray line beams of 100 µm length and waists below 100 nm, which in turn will enable improved material analysis [3,4].

References

[1] Ice et al, Science 334, 1234 (2011).
[2] Schroer et al, Appl. Phys. Lett. 87, 124103 (2005).
[3] Ludwig et al, JOM, 62, 22–28 (2010).
[4] Poulsen, J. Appl. Crystallogr., 45, 1084–1097 (2012).

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